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Two Issues Concerning Tonal Hierarchies: Comment on Castellano, Bharucha, and Krumhansl

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First, because tonal hierarchies exist in the music of long-established traditions, we may assume that they confer certain processing advantages. Such hierarchies capitalize on certain properties of the pitch memory system that do not require a tonal setting for demonstration. Furthermore, they facilitate the generation of hierarchical representations of sequential patterns of pitches, and such representations enable considerable parsimony of encoding. Second, the listener's establishment of a tonal hierarchy involves a process of key attribution. This process draws not only on the identities of the notes presented but also draws on their orderings. Certain sequential grouping factors are involved here that can also be shown to exist outside a tonal setting. We are therefore dealing with an elaborate bootstrapping operation, through which both a key and a sequential representation are arrived at by the listener.

The article by Castellano, Bharucha, and Krumhansl (1984) is one of an elegant and important series by Krumhansl and her colleagues concerning the cognitive representation of pitch in the context of tonal music. Previous work in this series has shown that, for the case of Western tonal music, the establishment of a key for the listener results in his or her invoking a hierarchy of prominence for the 12 notes of the chromatic scale, which is unique to that key. The present article shows further that analogous hierarchies are invoked on listening to Indian music also, indicating that this feature of musical processing occurs cross-culturally.

There are two issues arising from this study that I should like to address. First, what is the cognitive utility of such hierarchies? Second, what cues are employed by the listener in making the key attributions on which such hierarchies are based?

Given the existence of tonal hierarchies in the music of long-established traditions, it seems reasonable to assume that they confer some processing advantage. I should like to discuss two ways in which this can occur. First, as Krumhansl and her colleagues point out, the profiles that have been obtained for Western music correlate well with profiles of the relative durations for which different notes occur in various tonal compositions. Now, it has been shown in an atonal setting that when a note is repeated, recognition memory for this note is enhanced (Deutsch, 1975, 1982). This feature of tonal music therefore has the consequence that, when listening to a piece, a hierarchy of memorability for the different notes in the piece is created. Certain notes become firmly embedded in memory; others, less firmly; and so on. A further relevant observation is that recognition memory for a note is better when its two occurrences are separated by a sequence of intervening notes that form small melodic intervals rather than large ones. As the average interval size between temporally adjacent notes in a sequence increases, recognition performance declines (Deutsch, 1978). It is argued by Erickson (in press) that tonal music of many different traditions capitalizes on these two features of the pitch memory system. Such music can generally be characterized as consisting of a few anchor notes, which are well embedded in memory through repetition, together with a larger number of satellite notes, which are linked to the anchor notes by pitch proximity. On this line of reasoning, the hierarchies of promi-

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nence found in the present set of studies reflect the listeners' long-term exposure to a system that is conducive to good memory retention in a short-term situation.

A second argument concerns the establishment of representations for sequences of notes. It is generally agreed by music theorists that such sequences that exist in well-formed tonal music are best represented as hierarchies (Lerdahl & Jackendoff, 1983; Meyer, 1973; Narmour, 1977; Schenker, 1956/1979); and cognitive psychologists have pointed to the encoding advantages of hierarchical structures for sequential patterns (Greeno & Simon, 1974; Leewenberg, 1971; Restle, 1970; Simon, 1972; Simon & Kotovsky, 1963). Deutsch and Feroe (1981) proposed a model for the representation of sequences of notes in the form of hierarchies, and this model has been shown to enable considerable parsimony of encoding for segments of well-formed tonal music.

If representations of sequences of notes are indeed hierarchically structured, the question arises as to how the listener is able to generate such representations from the patterns of sound that he or she hears. Hierarchies of prominence for notes within different scales can serve as important cues. Assuming that the listener has assigned a key (discussed later), the notes built on a tonic triad are the most probable candidates for the highest level; the remaining notes in the diatonic scale come next, and so on. Knowledge of hierarchies of prominence can thus play an important role in the generation of parsimonious encodings by the listener, given the multitude of alternative representations from which he or she must choose.

This brings us to the second issue, namely, that of how the listener assigns a key to a passage, enabling the invocation of a particular hierarchy of prominence. In earlier works by Krumhansl and her colleagues, key attributions were induced by presenting the listener with certain "default" sequences, such as a major scale, or a major triad (assumed to be built on the tonic). In the Castellano et al. (1984) study, excerpts of established Indian music were presented instead, in which patterns of relative duration, metrical stress, and so on, would serve as salient cues for key attribution. But the further question then arises: Given a particular collection of notes, and given the absence of extraneous cues (such as differences in duration or loudness), are key assignments based simply on the identities of the notes in the collection or are the orderings of these notes also important? Butler and Brown (in press) argue for the latter view, and I do also and further suggest one factor that appears to be operating here.[1]

The sequence in Figure 1a, taken from Deutsch and Feroe (1981), strongly suggests the key of C major, and is described as an arpeggiation that ascends through the C major triad (C–E–G–C), with each note of the triad preceded by a neighbor establishment, thus forming 4 two-note patterns. So C major is clearly attributed, even though two of the notes (D# and F#) are not members of the appropriate diatonic collection. If adhering to this collection were of overwhelming importance, the key of E minor would be attributed instead. Now in this sequence, the notes of the C major triad are given metrical stress, and the C is repeated. If, however, we eliminate these two factors (as in Figure 1b) C major is still strongly suggested. Yet, if we simply present the retrograde of the sequence in Figure 1b, which is shown in Figure 1c, E minor is strongly suggested instead. This difference is not due to the absence of the C at the end of the sequence, because other orderings that retain this feature, such as shown in Figure 1d, strongly suggest E minor also.

How, then, do we explain the assignment of C major to the sequence in Figure 1b, and the assignment of E minor to its retrograde in Figure 1c? I suggest that, when presented with a sequence of notes, the listener forms low-level groupings on the basis of pitch proximity, and in the absence of other cues, assigns greater prominence to the last note of each grouping. Thus, given the sequence in Figure 1b, the groupings (D#–E) (F#–G) and (B–C) are formed. The notes E, G, and C are thus targeted to be combined at a higher level to form an arpeggiation of the C major triad, thus causing the listener to attribute the key

[1] Other factors must also be operating, such as implied harmonic motion, but because of space limitations these are not considered here.

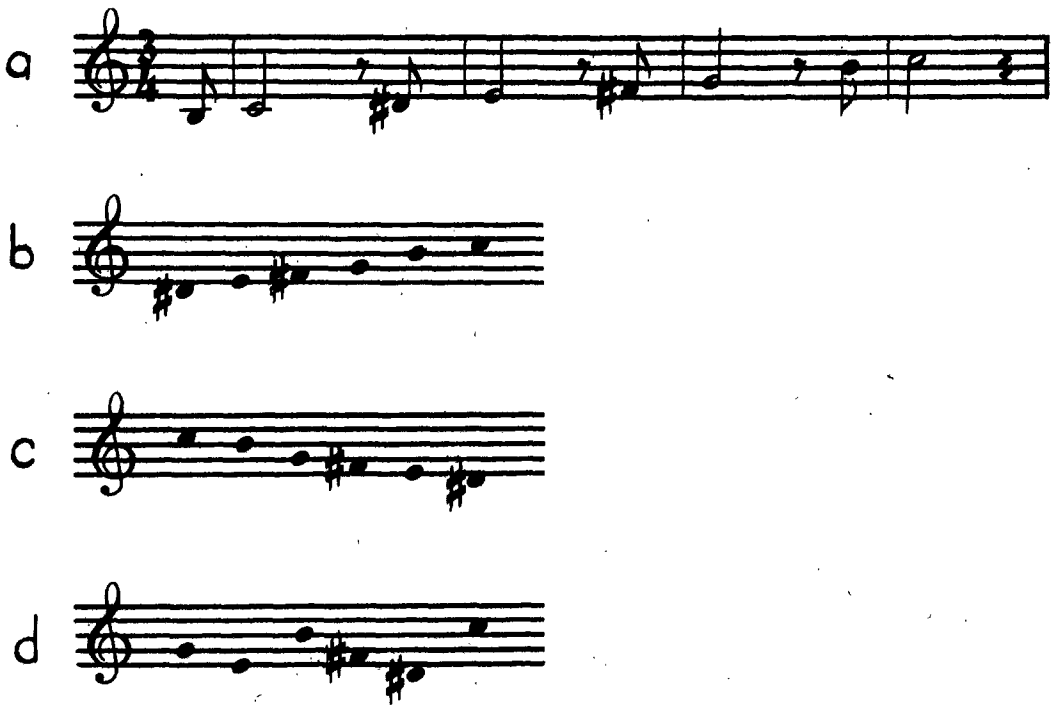

Figure 1. Sequential patterns to illustrate the effects on key attribution of different temporal orderings of a single collection of notes. (Pattern *a* is from "The Internal Representation of Pitch Sequences in Tonal Music" by D. Deutsch and J. Feroe, 1981, *Psychological Review, 88,* p. 504. Copyright 1981 by the American Psychological Association, Inc. Reprinted by permission.)

of C major. However, given the retrograde of this sequence, shown in Figure 1c, the notes B, F#, and D# are instead targeted to be combined at a higher level, thus forming an arpeggiation of the B major triad. Because this is the triad built on the dominant in the key of E minor, this key is now strongly suggested (and B major weakly so, despite the presence of notes outside the appropriate diatonic collection).

We can conclude from these examples that the process of key attribution, and thus of the establishment of a hierarchy of prominence for the different notes occurring in a passage, is indeed a complex one, involving low-level sequential grouping factors in addition to knowledge of the pitch collections concerned. However, as these examples also show, hypothesized hierarchies of prominence for the different notes must also be involved in the generation of sequential representations. It would appear that we are dealing with an elaborate bootstrapping operation, in which different types of cue feed back on each other, so that ultimately both a key and a sequential representation are arrived at by the listener.

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